Assessing the Costs of Power Outages in a Modern Economy

A Case Study from Cyprus

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Background

- Explosion in July 2011 destroyed 60% of national power generating capacity
  - 390 MW of steam turbine plants
  - 440 MW of combined cycle gas turbine plants
- Cyprus is electrically isolated
- Interruptions of electricity supply to consumers were implemented to cope with power shortage
- Emergency measures taken to eliminate shortages after summer 2011 (electricity imports, temporary rental of generators)

Research Questions

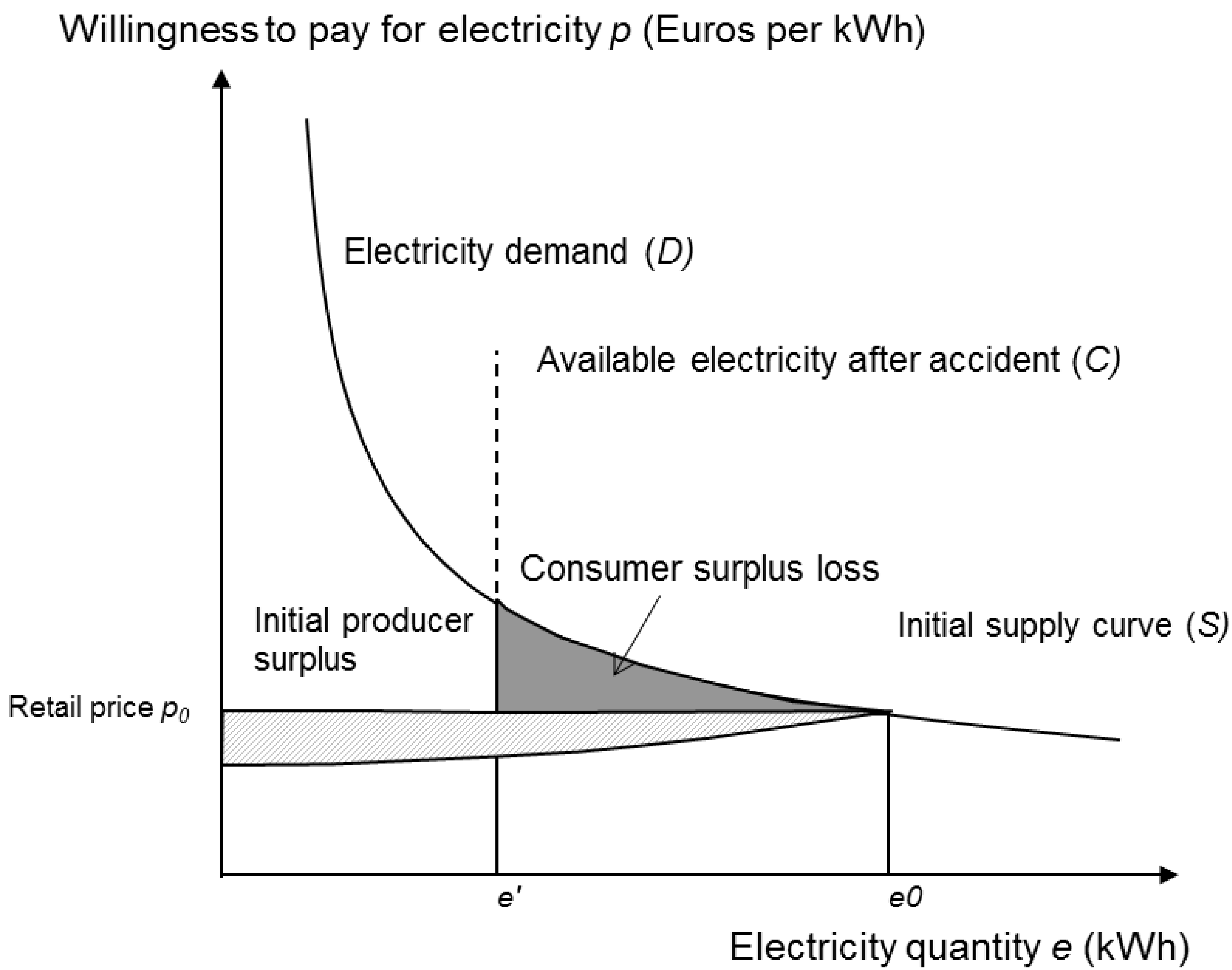
- How much did these power supply disruptions cost to households and firms?
- Were the supply-side emergency measures economically justified?
- Comparison of:
  - Costs of emergency measures
    vs.
  - Benefits, i.e. avoided economic losses thanks to these measures

(βλ. επίσης Πασιαρδής, Πασιουρτίδου & Ζαχαριάδης, Σχόλιο Οικονομικής Πολιτικής 23, ΚΟΕ, Παν/μιο Κύπρου, Αύγουστος 2011, http://www.ucy.ac.cy/erc/documents/Mari_Comment_03-08-11.pdf)

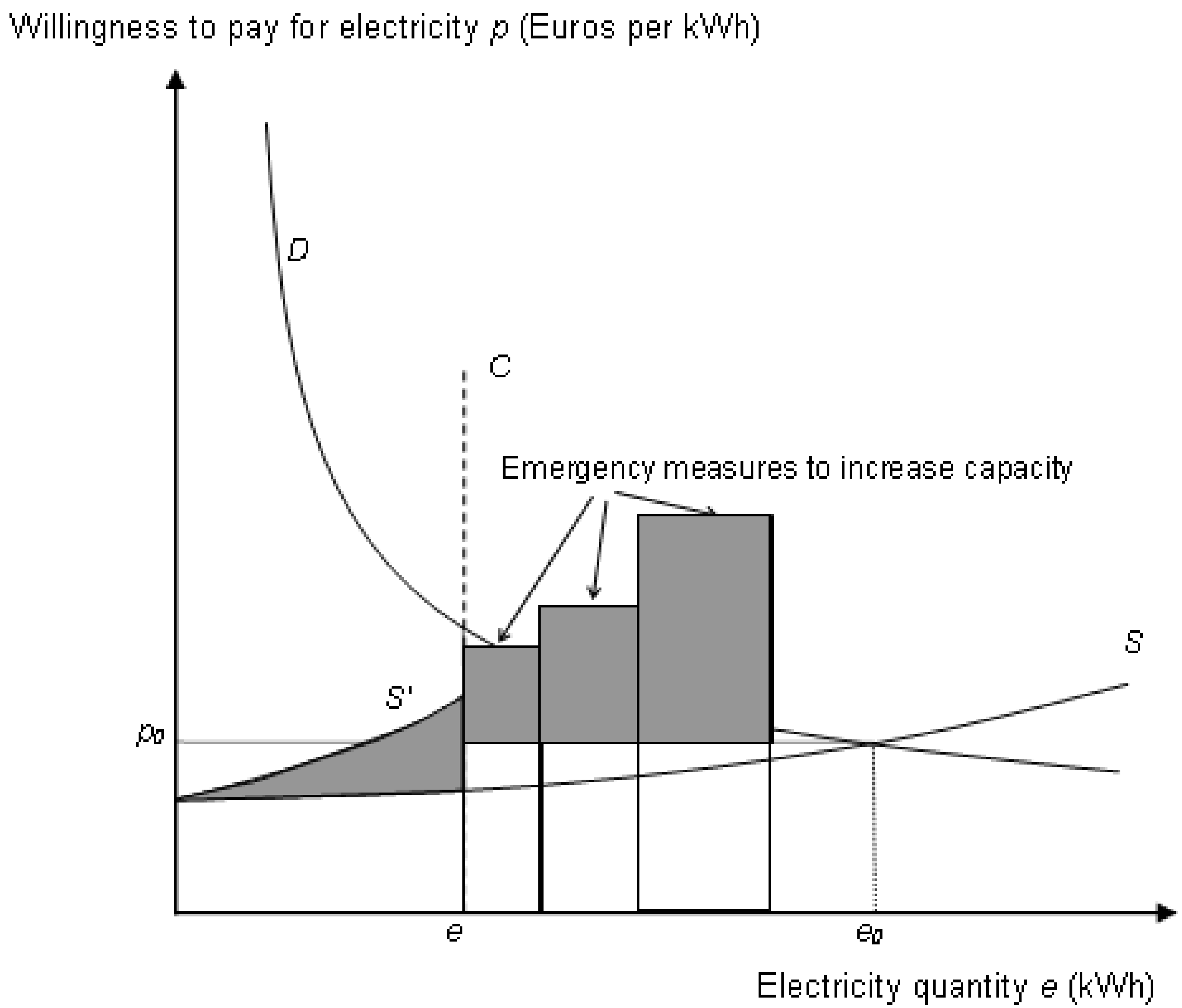
Economic & Engineering Approaches

1. Top-down economic analysis: Welfare losses due to power shortages (demand function approach)
2. Bottom-up engineering analysis: The costs of emergency measures to increase the available capacity
3. Economic assessment of the value of lost electricity (production function):
   - Annual average values
   - Estimates by hour/day/season

Methodology to assess costs of power shortages with a demand function



Changes in supply curve to replace lost power capacity in an emergency



Welfare Losses Due to Power Shortages

- Model of consumer demand for electricity as a function of electricity prices, income and other variables
- Time-series econometric estimation with vector error correction (VEC) and autoregressive distributed lag (ARDL) specifications
- Identification of demand for electricity by type of consumer

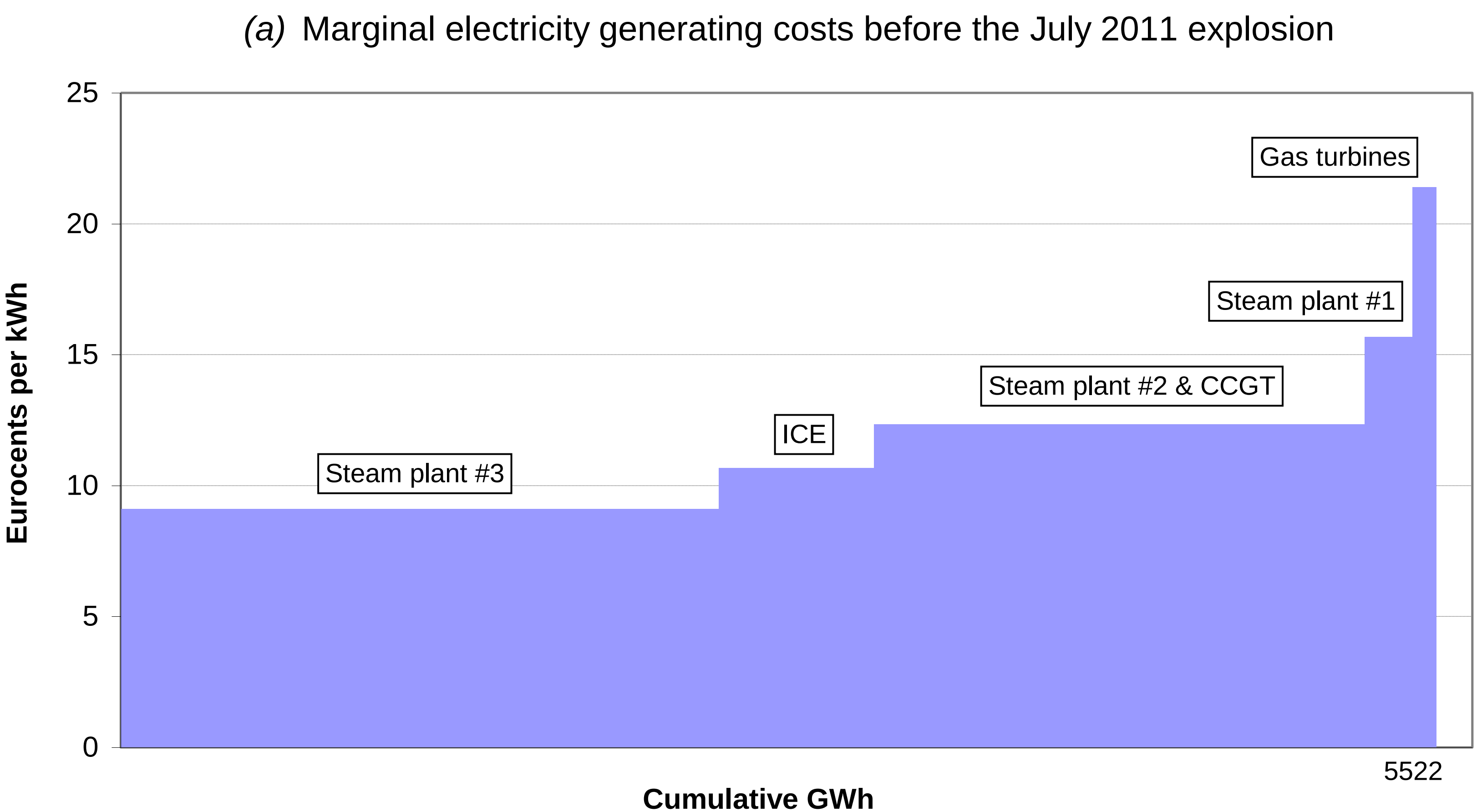
⇨ Simulations of welfare losses due to restrictions in consumed quantities

Welfare Losses Due to Power Shortages

Simulations of real-world power interruptions by type of consumer and their associated costs

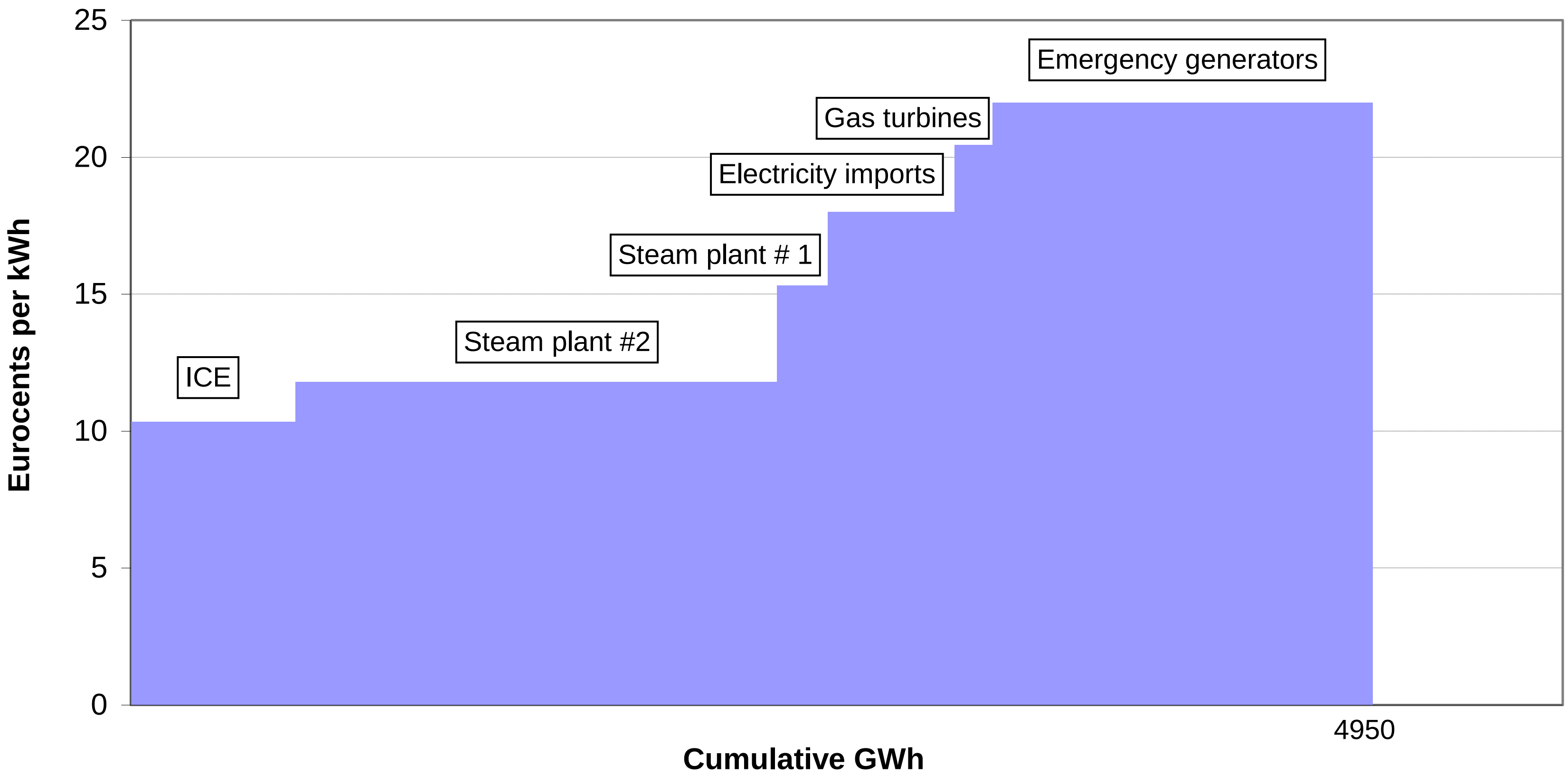
	Annual cost (million Euros at 2010 prices)		
Sector	*Without emergency measures*	*With emergency measures*	*Difference*
Industrial	2.3	0.0	2.3
Services	215.4	100.2	115.2
Residential	179.7	91.6	88.1
Total	**397.4**	**192.6**	**205.6**

Bottom-Up Engineering Analysis – 1



Bottom-Up Engineering Analysis – 2

(b) Marginal electricity generating costs after the July 2011 explosion



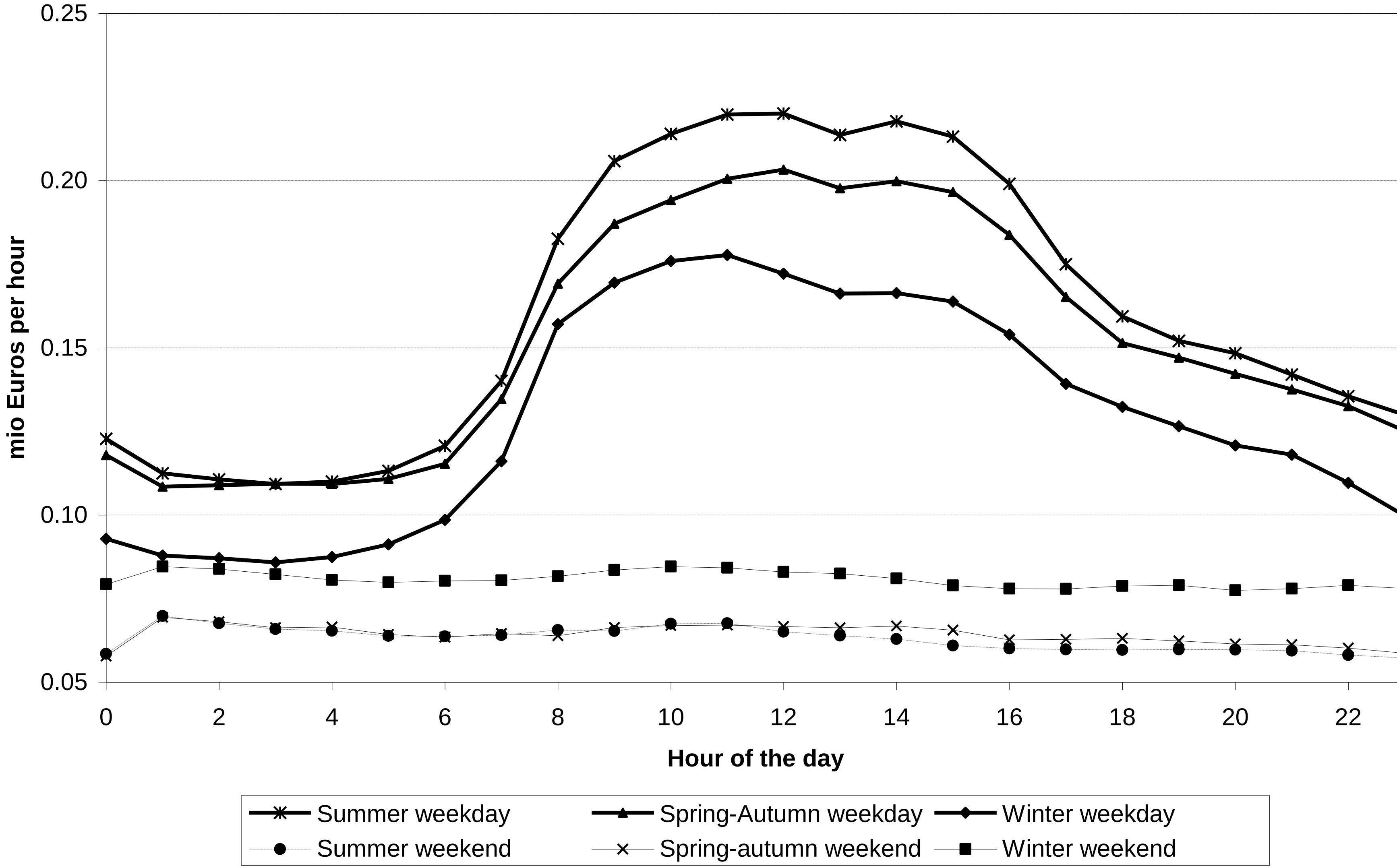
Costs to Electricity Authority with & without Emergency Measures (in M€'2010)

Electricity generation costs	
before the accident	*601.5*
after the accident, with emergency measures	*777.1*
after the accident, without emergency measures	*356.1*
Change in costs with and without measures	421.0
Sales revenues of electricity authority	
before the accident	*776.0*
after the accident, with emergency measures	*694.8*
after the accident, without emergency measures	*413.3*
Change in revenues with and without measures	281.5
Sales revenues net of generating costs	
before the accident	*174.5*
after the accident with emergency measures	*-82.3*
after the accident without emergency measures	*57.2*
Net additional costs of emergency measures	**139.6**

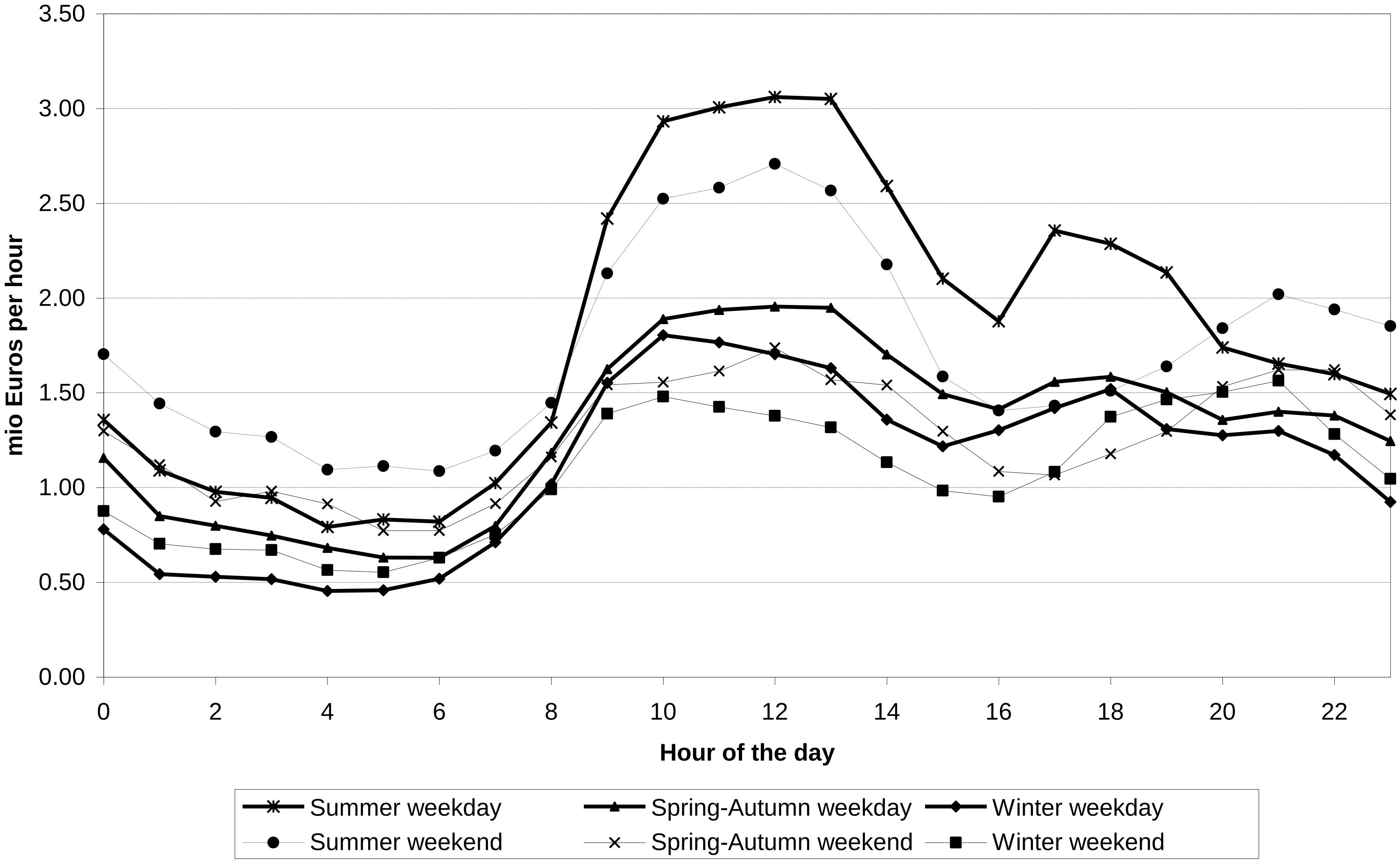
Annual Value of Lost Electricity, Cyprus 2009

Sector	Electricity consumption (GWh)	Value (mio €)	Value of lost load (€/kWh)
Agriculture	151	346	2.30
Mining & quarrying	27	52	1.90
Manufacturing	546	1043	1.91
cement industry	*133*	*120*	*0.90*
Gas & water supply	249	51	0.20
Construction	11	1249	118.06
Services	1999	12243	6.12
Public administration	*135*	*1570*	*11.63*
Private offices	*397*	*5551*	*13.97*
Health	*94*	*628*	*6.65*
Trade	*467*	*1872*	*4.00*
Hotels & restaurants	*485*	*915*	*1.89*
Education	*38*	*960*	*25.48*
Other	*382*	*747*	*1.96*
Residential	1722	15614	9.07
Total	4706	30598	6.50

Value of Electricity in Industry, Cyprus 2009



Value of Electricity in Services, Cyprus 2009



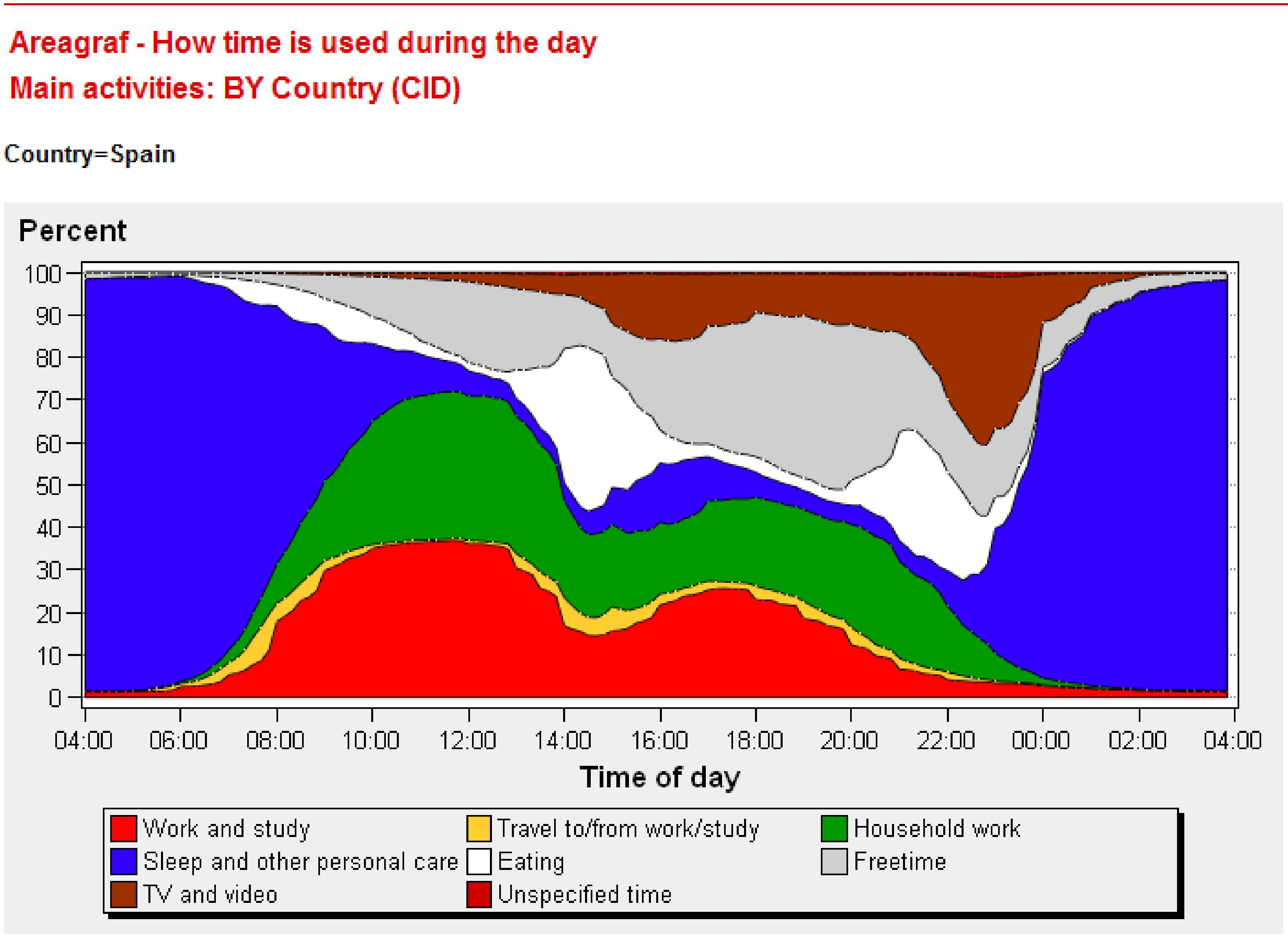
Assessing Value of Electricity in Households

- Value of residential electricity depends also on the activities carried out by house occupants in different hours of the day
  - ➢ E.g. a 1-hour outage at night vs. 1-hour outage in afternoon
- Constructed matrix of household activities by hour, season (summer, winter or spring-autumn) and day of the week (weekday or weekend)
- 3 types of activities:
  - ➢ paid work at home (VOLL = net hourly wage)
  - ➢ leisure and domestic activities (half of paid work VOLL)
  - ➢ sleep and outdoor activities (VOLL = 0).

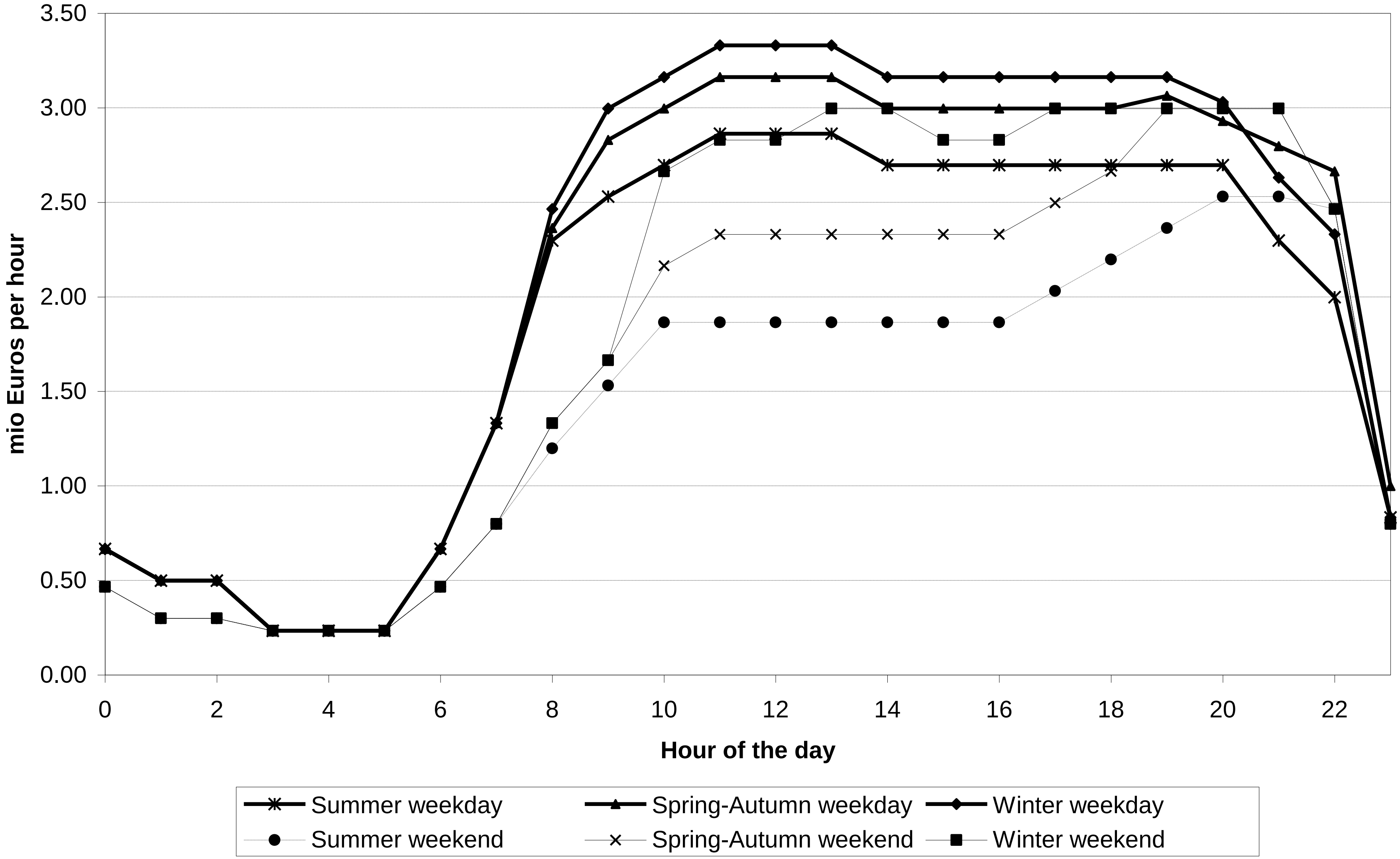
⇨ Hourly household activities not available for Cyprus, obtained from European Harmonised Time Use Survey for Mediterranean countries

Example of Time Use Survey results

(https://www.h2.scb.se/tus/tus/AreaGraphCID.html)



Value of Electricity in Households, Cyprus 2009



Economic Losses Due to Power Shortages Based on Time-Varying Profiles

Sector	*without emergency measures*	*with emergency measures*	*Difference*
Industrial	19	0	19
Services	531	261	270
Residential	2168	579	1590
Total losses	**2718**	**840**	**1878**

- Distribution of economic damage similar to ‘demand function’ approach
- *But total losses an order of magnitude larger!*
- Several possible reasons for under- or overestimation of losses with each method

Conclusions – 1

- Assessing the real-world costs of prolonged power outages is a highly uncertain exercise
- Extra costs due to emergency measures are markedly lower than the low-end welfare loss estimates

⇨ Response of authorities to the electricity crisis were generally appropriate (not necessarily optimal)

- Reasonable due to small country size, one electricity company, good engineering knowledge of supply and demand structure

Conclusions – 2

- It is not clear whether power interruptions were implemented in economically optimal way
- The value created by households is ignored in engineering decisions of outages
- Energy authorities are mainly concerned with avoiding interruptions of electricity in industries, hotels and offices.
- *But* according to standard economic analysis the optimal response is to secure uninterrupted supply to users with high VOLL, i.e. households!

Conclusions – 3

- Production function approach to be treated with caution in case of prolonged outages:
  - Consumers adapt gradually so that the welfare losses on an annual basis may be lower than initially calculated
  - Repeated power disruptions may be more serious for firms than what a linear production function assumes
  - Reliability is a key aspect in internationally tradable sectors, so that repeated outages may be detrimental for key parts of the Cypriot economy such as tourism or banking

⇨ Combination of economic and engineering approaches extremely useful for managing an energy crisis